International Journal of Gastronomy and Food Science 28 (2022) 100524

Contents lists available at ScienceDirect

International Journal of Gastronomy and Food Science

journal homepage: www.elsevier.com/locate/ijgfs

Incorporation of roe, milt and liver from plaice (*Pleuronectes platessa*), herring (*Clupea harengus*) and cod (*Gadus morhua*) in newly developed seafood Pâtés: Sensory evaluation by teenage consumers in Ireland and their attitudes to seafood

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ARTICLE INFO

Keywords:
By-products
Fish
New product development
TDS

ABSTRACT

Roe, milt and liver of marine fish caught in Irish fisheries are generally discarded at sea or processed on-shore as low-value fishmeal. This study aimed to 1) develop new added-value seafood products using roe, milt and liver; 2) determine eating quality and acceptance among teenagers; and 3) survey teenagers' attitudes towards seafood consumption. Four pâtés were developed by combining marine ingredients in varying proportions: 1) 100% plaice roe (RO), 2) 75% roe/25% milt (RM), 3) 75% roe/25% liver (RL) and 4) 75% roe/12.5% liver/12.5% milt (RLM) with plant-based ingredients. Physico-chemical, colour and texture analyses were conducted. Sensory evaluation using temporal dominance of sensations (TDS) and acceptance testing (hedonic and JAR scales) with 72 subjects aged 15–16 years were undertaken. Fat content ranged from 4% in RO to 15% in RL, while protein ranged from 21% to 17%, respectively. Significant L*a*b* differences ($p < 0.05$) resulted in a 'great' total colour difference ($\Delta E^* = 11.56$) between RO and RL. TDS curves indicated fish flavour and saltiness as the main attributes significantly dominating during oral processing. Flavour was important in overall acceptance, with perception of products being 'too-fishy' negatively impacting overall liking. Cumulative positive responses ('like slightly' to 'like extremely') for RO, RLM, RL and RM were 52%, 48%, 39% and 36%, respectively. Reported seafood consumption was relatively low (9% of respondents eating fish more than twice a week and 36% once a month or less). A positive correlation between overall liking and 'desire to eat more seafood' was observed. Approximately 33% of students stated they would consider snacking with the new pâtés. Positive acceptance of new products, along with positive attitude towards seafood and willingness to try new species suggests that roe, milt and liver could be incorporated into seafood formulations for healthy snacks in the Irish teenage market.

Incorporation of roe, milt and liver from plaice (*Pleuronectes platessa*), herring (*Clupea harengus*) and cod (*Gadus morhua*) in newly developed seafood pâtés: sensory evaluation by teenage consumers in Ireland and their attitudes to seafood.

1. Introduction

Consumption of seafood in Ireland has grown from 15 kg/capita in 1961 (Curtin, 2019) to a reasonably stable level of 22.1 kg/capita in 2015 (EUMOFA, 2017), but remains lower than the EU average of 25.1 kg/capital in 2015. That said, few people in Europe achieve the recommended intake of at least two portions of fish a week, one of which should be oily (Careche et al., 2011). Porcine meat is the main animal-based food category consumed in Ireland followed by poultry meat, with bovine meat and seafood consumed at similar levels (Curtin, 2019). The most consumed fish species in Ireland are salmon and cod (EUMOFA, 2017) accounting for 56% of the total consumption of fresh fish products in Ireland. Safefood, Ireland's all-island food safety promotion board, (2012) have indicated that one in five Irish people never eat fish, while it was estimated two thirds of children did not eat fish. Barriers to eating fish include smell, taste, appearance and presence of bones (Leek et al., 2000).

Fish liver, milt and roe typically are not consumed in Ireland. These

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https://doi.org/10.1016/j.ijgfs.2022.100524
Received 26 November 2021; Received in revised form 15 March 2022; Accepted 4 April 2022
Available online 7 April 2022

Table 1
Formulation of four pâtés (RO, RM, RL, and RLM) in grams.

Pâté	Roe (g)	Milt (g)	Liver (g)	Rapeseed oil (g)	Remaining ingredients (g)
RO	100	0	0	4	32.6
RM	75	25	0	4	32.6
RL	75	0	25	0	32.6
RLM	75	12.5	12.5	0	32.6

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

ingredients are rich in marine lipids and proteins (Rustad et al., 2011) and contain essential fatty acids and essential amino acids. These nutritious ingredients are often discarded as waste at sea during onboard gutting of fish or used for low-value fish meal production when commercially processed on-shore (Archer et al., 2001). It is estimated that fish viscera (including roe, milt and liver) accounts for 10–25% of total fish weight (EUMOFA, 2018) and as such represents a significant amount of potential food waste. As Ireland is an important fishing and spawning ground (Gerritsen and Kelly, 2019), this offers the opportunity to transform these underused no-value/low-value waste streams into more profitable foodstuffs to enhance human nutrition in line with government's National Policy Statement on the Bioeconomy (Department of the Taoiseach, 2018) (Hayes, 2015) and thereby add value to Irelands fishing industry.

Fish roe is, to some degree, consumed in Europe in the form of processed/salted seafood products (e.g. caviar, bottarga, taramasalata) (Bledsoe et al., 2003), while milt and liver are consumed to a much lesser extent. Although herring milt has recently been developed as a food additive for malnourished children in developing countries (Bjørndal et al., 2012), it is still generally treated as waste product (Wang et al., 2020). In Norway, one of the largest global fish and fish roe producers (Ahuja et al., 2020) (Monfort, 2002) milt, roe and liver go into produce feed production for fish and domestic animals (Paluchowski et al., 2016). During spawning season, plaice roe contains significant amounts of protein (c. 30% wet weight) and lipid (c. 3% wet weight) (Dawson and Grimm, 1980) while herring milt contains 15–24% protein (wet weight) and c. 1–3% lipid (wet weight) (Bjørndal et al., 2012; Dementeva and Voropaeva, 2014; Egede-Nissen et al., 2012). Cod livers are a rich source of long chain polyunsaturated fatty acids and vitamin D, consisting of 55–66% lipids (wet weight) and c. 5% protein (wet weight) (Batista, 2007; Guil-Guerrero et al., 2011).

Provision of healthy and affordable products by Irelands food industry will help to play an important role in combating obesity in a country where one in four children are overweight or obese (Department of Health, 2016). Roe, milt, and liver could be incorporated into nutritious savoury food products to provide healthier snack choices. The aim of this study was therefore to a) develop nutritious convenient spreadable seafood products using roe in combination with milt and fish liver; b) determine the products eating quality and acceptance among teenagers; and c) survey teenager's attitudes towards seafood consumption.

2. Methods

2.1. Pâté (roe-based spread) production

Atlantic herring (*Clupea harengus*) milt, Atlantic cod (*Gadus morhua*) liver and plaice (*Pleuronectes platessa*) roe were sourced via local fishmongers. These ingredients were placed in frozen storage (−20 °C) until analysis. Formulation and processing of pâtés was refined to enhance texture, flavour and visual appeal of products. Pâté formulations were developed during a series of preliminary trials (date not shown) and contained 100 g fish ingredients (roe/milt/liver) in varying amounts along with oat flour (2.7 g), parsnip (14 g, grated), onion (8 g, finely chopped), tomato paste (6 g), dill (0.08 g, dried), nutmeg (0.14 g, powdered), salt (1.5 g, fine) and pepper (0.2 g, white, powdered). Four pâtés were developed by combining fish ingredients in varying proportions: 1) 100% plaice roe (RO), 2) 75% roe/25% milt (RM), 3) 75% roe/25% liver (RL) and 4) 75% roe/12.5% liver/12.5% milt (RLM) with the remaining ingredients listed previously. Rapeseed oil (4 g) was added to RO and RM but not added to pâtés containing liver (RL and RLM) as this ingredient is naturally very high in fat (Guil-Guerrero et al., 2011) (Table 1).

Fish ingredients were defrosted prior to use. Ingredients were blended in a mixer (700 W, 19000 rpm, Hoyer Handel GmbH, Hamburg, Germany) for 10 s. Residual ingredients, which had adhered to the inside of the blender walls and blades, were gathered and folded back into the main mixture. The mixture was blended for a further 10 s to form a smooth emulsion. Then 115 g of mixture was transferred to 100 ml glass jars and oven cooked (16.5 kW, CsE111264, MKN GmbH & Co, Wolfenbüttel, Germany) for 45 min at 90 °C. Products were cooled rapidly in a blast chiller for 2 h prior to refrigerated storage at 3 °C.

2.2. Proximate composition and energy value

The proximate composition end energy value of each pâté product was analysed (n = 2). Fat content was determined by Nuclear Magnetic Resonance (NMR) method (AOAC, 2005). Protein was determined using the Dumas method (ISO, 2009) (conversion factor 6.25). Total carbohydrate was determined by difference. Moisture content was determined according to the AOAC (2005) method (gravimetric determination of dry matter and determination by calculation). Ash was determined by gravimetric method (CSN, 1993). Energy value was calculated as per Annex XIV of European Union Regulation No 1169/2011 (European Commission, 2011).

2.3. Instrumental colour

Colour measurements were carried out using a Chroma Meter CR-400 (Konica Minolta Inc., Osaka, Japan) using CR-A33F glass light projection tube. Absolute values of tristimulus CIE L*, a*, b* colour scale was used to record lightness, redness and yellowness respectively using illuminant D_{65}, 8 mm aperture and 0° viewing angle. Total colour difference (ΔE) was calculated from the difference in colour co-ordinates (L*, a*, b*) between pâtés according to ISO/CIE 11664-4 (ISO, 2019) (equation (1)). Products were removed from refrigerated storage after 24 h. Lids were removed and 5 colour measurements were taken at the exposed surface of the pâté and averaged (n = 4 batches).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

2.4. Instrumental texture

Penetration tests were carried out at 4 °C using a TA-XT2 texture analyzer (Stable Micro Systems, Surrey, UK) equipped with a 25 kg load-cell using P/0.5HS (12.7 mm diameter) hemispherical probe at a speed of 1.5 mm/s and a compression depth of 8 mm (Estévez et al., 2006). Peak force was recorded as hardness (N) of sample (n = 6 batches).

2.5. pH measurement

The pH was measured using pH probe (pH150, Eutech Instruments, Vernon Hills, USA) whereby 5 g samples (n = 3 batches) were mixed thoroughly with 5 g distilled water to produce a slurry. pH measurements were carried out in triplicate and results averaged.

2.6. Sensory evaluation

Sensory evaluation was carried out in two Second-Level schools (students typically aged 12–18 years old), by students from the Irish transition year programme (typically aged 15 years), to establish

Table 2
Proximate composition and energy value of four pâtés (n = 2).

Parameter	RO	RM	RL	RLM
Fat (g/100 g)	4.1 ± 0.2[c]	4.2 ± 0.2[c]	14.3 ± 1.0[a]	8.5 ± 0.5[b]
Proteins (g/100 g)	20.6 ± 0.9[a]	20.3 ± 0.9[ab]	17.5 ± 0.1[b]	18.7 ± 0.6[ab]
Carbohydrates (g/100 g)	6.6 ± 1.4 [a]	4.7 ± 0.7 [a]	6.3 ± 0.1 [a]	6.0 ± 0.8 [a]
Ash (g/100 g)	1.8 ± 0.3 [a]	2.2 ± 0.1 [a]	1.9 ± 0.1 [a]	2.2 ± 0.1 [a]
Moisture (g/100 g)	67.0 ± 0.4 [a]	68.7 ± 0.1 [a]	60.2 ± 0.9 [a]	71.6 ± 9.1 [a]
Energy (kcal/100 g)	147 ± 4.2 [c]	138.5 ± 0.7 [c]	222.5 ± 7.8 [a]	175 ± 5.7 [b]

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt. [a-c] = Different superscript letters represent statistically significant differences between group means in rows following ANOVA and Tukey's post hoc test ($p < 0.05$).

acceptance of fish pâté incorporating roe, milt and liver. A subset of teenage demographic was chosen for this study as very little data exists on fish consumption in this age group in Ireland and research on children is known to help with understanding acceptance/rejection of foods (Tuorila and Hartmann, 2020). Data from the United Kingdom (UK) suggests about one third of children (aged <12 years) consume fish and that young people (aged 4–18years) were consuming approximately half the amount of fish to UK adults (Safefood, 2012). Data were collected using Compusense® Cloud (Ontario, Canada) sensory evaluation software via laptops, touchscreen tablets or smart phones.

Prior to the evaluations, food safety of the products was ensured by performing microbial analysis for ready to eat products by an accredited laboratory as per Commission Regulation No 2073/2005 (European Commission, 2005). Ethical approval was granted by the Institute[2] prior to the study. Due to the restrictions caused by the Covid19 pandemic, parental consent was obtained using Microsoft Forms prior to arrival at the school as per school guidelines. Only children suffering from food allergies were excluded from the study.

Sensory evaluation of four pâtés was carried out as part of a 2-h Food Science workshop delivered to schools in December 2020. The workshop commenced with a 30 min presentation introducing the field of Food Science & Technology focussing on Sensory Science in the context of food product development. Detailed explanations of the five senses and all scales and sensory attributes listed in the questionnaire were provided as part of the workshop. Examples of questions from the sensory questionnaire were given and the concept of perception of dominance in the context of Temporal Dominance of Sensations (TDS) was discussed. In this instance dominance was defined as "the attribute that triggers your attention the most" based on Pineau and Schilch (2015). Students were instructed to select the most dominant sensory attribute on the screen while eating the pâté sample. In this context, students were asked to imagine an orchestra (Silva et al., 2018) as an analogy to tasting the food, where "the dominant instrument [analogous to attribute] is the one that you hear at a given time while enjoying the music as a whole, different instruments may stand out at different times of the performance". Following detailed instructions, the students then carried out the evaluations. Sensory tests were performed in a large classroom setting with each student positioned 1 m apart at a separate desk (in line with public health guidance during the Covid19 pandemic).

An average of 17 (±3) students attended each workshop. A total of five workshops were conducted. The pâtés were stored in a polystyrene cooler box containing ice-blocks to maintain a temperature of 3 °C. The pâtés were removed from cold storage immediately prior to sensory assessment. Approximately 3 g of pâté was spread on two plain crackers and placed in white plastic containers coded with a 3-digit random number. Samples were presented in random monadic order with balanced complete block design (O'Sullivan, 2016).

TDS was measured first, followed by acceptance testing using 9-point hedonic scales and 5-point just-about-right (JAR) scales. For the TDS, twelve key sensory attributes relating to these products were developed duringprevious preliminary sensory analyses (data not shown) undertaken by culinary and food experts experienced in sensory evaluation during the initial food product development stage. TDS attributes (bitter, metallic, pasty, salty, sweet, fish flavour, sour, spicy, pepper, floral, astringent e.g. dry, and savoury) appeared on the panellists device screens in a balanced random order to reduce the effect of only using the first few attributes in the list (Pineau et al., 2012). Panellists were instructed to place the food sample in their mouth and then immediately press the start button on their screen and commence their evaluation as they chewed and swallowed. Panellists were given 30 s to select the dominant tastes and flavours. Chance level was calculated at 0.08 (1 in 12 attributes).

Students then rated their liking of: appearance, colour, consistency, aroma, flavour, mouthfeel and overall liking using 9-point hedonic labelled left to right: 1 = dislike extremely to 9 = like extremely (Lawless and Heymann, 2010). The degree of acceptability of fishiness (fish flavour), saltiness, savouriness, bitterness and astringency were measured using JAR ordinal scale (1 = not nearly enough, 3 = JAR, 5 = much too) (Gacula et al., 2007). Mandatory comment boxes encouraged assessors to add positive and negative comments about the product. Students were instructed to type "na" where no negative/positive comment applied, in order not to force a comment where none existed. Finally, teenagers were asked "if this product was purchased for you, e.g. by parent/guardian, would you consider eating it as a snack?" this was assessed using a 5-point Likert scale (1 = definitely will not eat, to 5 = definitely will eat).

2.7. Attitudes and preference questionnaire design

At the end of the sensory evaluation task the students were presented with a series of questions regarding their attitudes to and consumption of seafood as well as brief demographic questions. Demographic questions included age, gender and community type (e.g. urban/rural). Ten questions were posed to determine frequency and types of seafood and snacks consumed based on Erdogan et al. (2011) using a mixture of: open-ended questions; check-all-that-apply; dichotomous, 3-point or 7-point scales. A further 23 questions (test items) were posed to explore attitudes to healthiness of seafood and attitudes to seafood eating quality/cooking (Leek et al., 2000) (Hicks et al., 2008). For the purposes of this questionnaire, seafood was defined as "any food product made using one or more fish/shellfish species as the main ingredient". Attitudes to a series of statements were evaluated using 7-point Likert scale (1 = "strongly disagree" to 7 = "strongly agree", with "neither agree nor disagree" as the midpoint) (Domegan and Fleming, 2003). The questionnaire was reviewed for content validity and reliability of attitude scores was examined using Cronbach's alpha.

2.8. Statistical analysis

Statistical analysis was carried out using XLSTAT (Addinsoft, 2022). Statistical differences between means were determined using one-way analysis of variance (ANOVA) and Tukey' HSD *post hoc* pairwise comparison tests. A level of $p < 0.05$ was used to establish significant differences among means.

TDS curves, chance and significance levels were calculated using Compusense ® Cloud (Ontario, Canada) software. An attribute was considered significantly dominant when the corresponding curve was above the significance limit visible on each plot. Fisher's exact test was carried out to show significant differences between pairs of product. Kolmogorov-Smirnov test (K–S test) was used to compare the observed distributions of hedonic and JAR scores. Penalty analysis was used to determine impact of JAR attributes on overall liking, if any. The not-JAR responses (i.e. too little or too much) of a particular attribute which received ≥20% of the responses were considered for penalty analysis

Table 3
Average CIE L*a*b* colour values, instrumental hardness, and pH of pâtés (±s.d.).

Pâtés	L*	a*	b*	Hardness (N)	pH
RO	55.76^{d} (±3.11)	9.58^{a} (±1.31)	20.62^{a} (±1.32)	0.39^{b} (±0.09)	5.98^{ab} (±0.05)
RM	60.64^{c} (±1.27)	7.70^{b} (±0.53)	18.05^{c} (±0.89)	0.36^{b} (±0.06)	6.03^{a} (±0.04)
RL	67.14^{a} (±1.52)	7.57^{b} (±1.02)	20.53^{a} (±1.17)	0.92^{a} (±0.29)	5.79^{c} (±0.08)
RLM	65.17^{b} (±2.12)	7.35^{b} (±0.47)	18.94^{b} (±0.72)	0.74^{a} (±0.19)	5.92^{b} (±0.03)

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt. CIE colour scale L* = light (51–100) vs. dark (0–50), a* = red (positive number) vs. green (negative number), b* = yellow (positive number) vs blue (negative number). $^{a\text{-}d}$ = Different superscript letters represent statistically significant differences between group means in columns following ANOVA and Tukey's post hoc test ($p < 0.05$).

Table 4
Total colour difference (ΔE) between pâtés.

Contrast	ΔE	Contrast	ΔE
RO versus RM	5.83	RM versus RL	6.96
RO versus RL	11.56	RM versus RLM	4.62
RO versus RLM	9.81	RL versus RLM	2.55

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

(Narayanan et al., 2014). Agglomerative Hierarchical Clustering (AHC) was carried out (Ward's method) using overall liking from sensory data (Schilling and Coggins, 2007). Comment analysis was carried out using correspondence analysis of modality contingency table. Spearman's correlation coefficient test was used to compare attributes from acceptance testing. Cronbach's alpha coefficient was used to measure internal consistency of the Likert-scale attitude data relating to healthiness and seafood consumption.

3. Results and discussion

3.1. Physicochemical analysis: proximate composition, instrumental colour, pH and texture

Proximate composition of the four pâtés is presented in Table 2. Fat content was highest for RL and lowest for RM, conversely, protein content was highest from RM and lowest for RL. This was to be expected as cod livers are a richer source of lipids compared to roe and milt. Cod livers typically contain 55–66 g/100 g lipids and ca. 5 g/100 g protein (Batista, 2007; Guil-Guerrero et al., 2011; Zárate et al., 2017). Dawson and Grimm (1980) reported lipid and protein content in plaice roe at approximately 3 g and 30 g/100 g respectively. Herring milt lipid

Table 5
Average values for acceptance of attributes of pâtés– 9-point hedonic scale (±s.d.) and percentage "like" response for Overall Liking category (from 6 to 9 on the hedonic scale).

Attribute	RO	RM	RL	RLM	Significance
Colour	5.06 (±1.91)	4.99 (±1.92)	4.91 (±1.99)	4.93 (±2.12)	NS
Appearance	4.97 (±1.89)	4.73 (±1.90)	5.14 (±1.92)	4.92 (±2.01)	NS
Consistency	5.24 (±1.92)	5.20 (±1.88)	5.26 (±2.19)	5.11 (±2.15)	NS
Aroma	5.08 (±2.08)	4.57 (±1.92)	4.87 (±2.26)	4.71 (±2.09)	NS
Flavour	5.25 (±2.40)	4.67 (±2.41)	4.81 (±2.42)	5.07 (±2.50)	NS
Mouthfeel	5.32 (±2.04)	5.07 (±1.97)	5.10 (±2.11)	5.08 (±2.11)	NS
Overall liking	5.23 (±2.32)	4.81 (±2.34)	4.73 (±2.33)	5.14 (±2.38)	NS
% "like" slightly to extremely	52	36	40	47	
% "like moderately" to "extremely"	31	29	29	33	
% "like extremely"	3	3	1	6	

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt. NS = not statistically significant differences. between group means in rows as determined by one-way ANOVA ($p < 0.05$).

Table 6
Students reported intention to eat pâté's as a snack if purchased by a parent or guardian.

Pâtés	Definitely will not eat	Probably will not eat	Might or might not eat	Probably will eat	Definitely will eat
RO	26.8	22.5	11.3	26.8	12.7
RM	22.9	30.0	21.4	18.6	7.1
RL	27.1	25.7	18.6	20.0	8.6
RLM	31.0	18.3	14.1	25.4	11.3
Average	27.0	24.1	16.3	22.7	9.9

RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

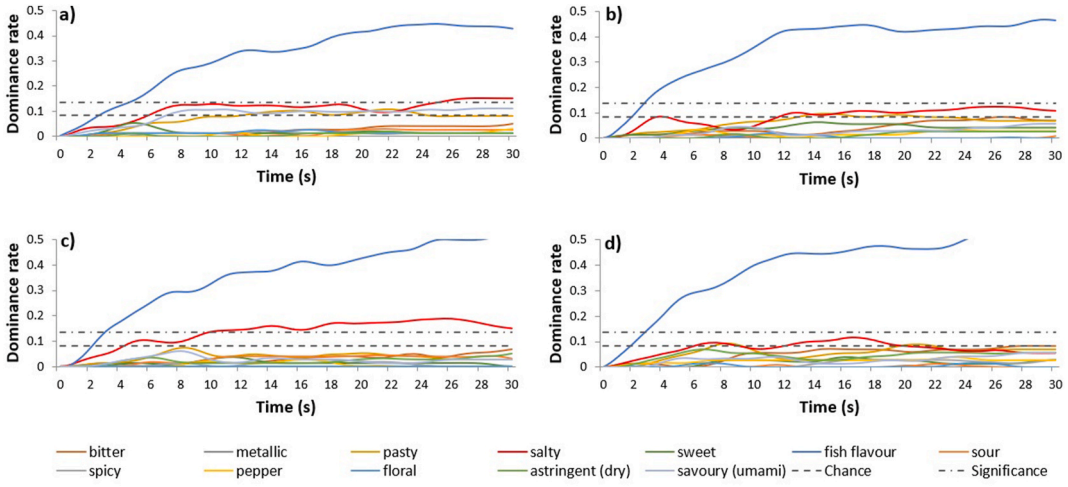

Fig. 1. Temporal dominance of sensations (TDS) curves of dominance rate versus time (s) for pâtés: a) Roe only; b) Roe & Milt; c) Roe & Liver; d) Roe, Liver & Milt.

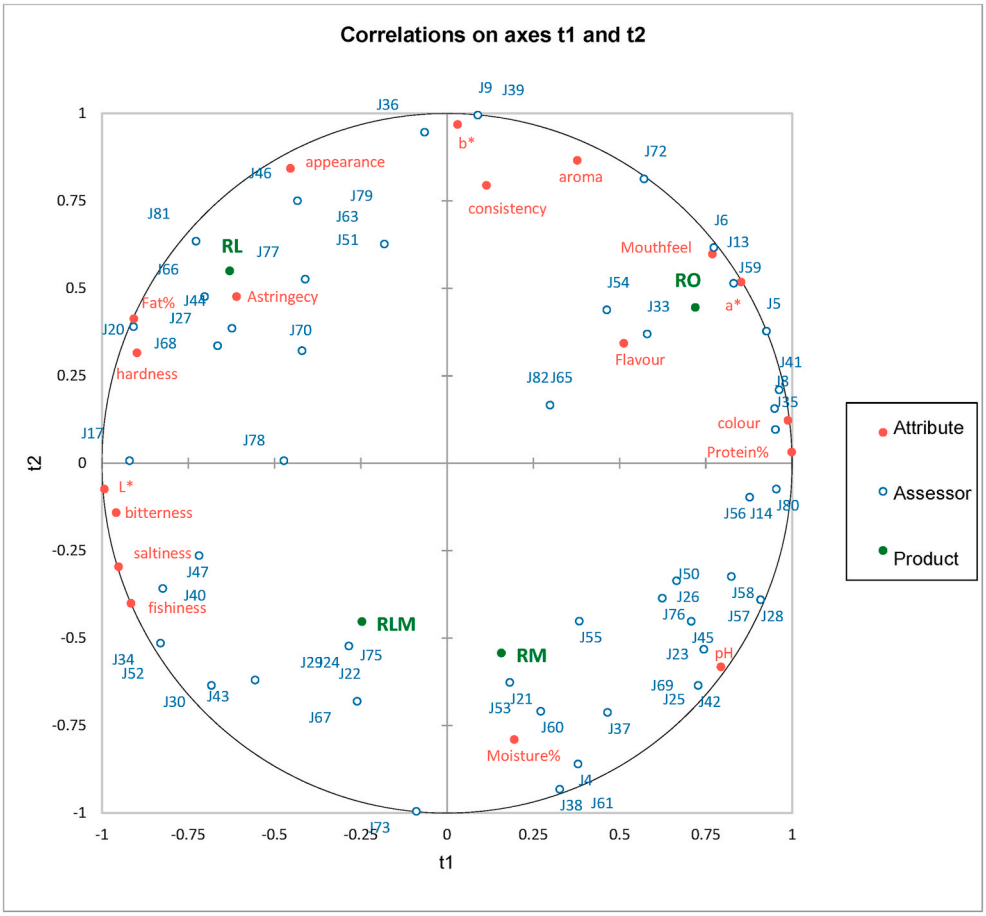

Fig. 2. PLS correlation plot, mapping overall liking responses from assessors (J) of pâté products (RO, RM, RL, RLM) with physico-chemical parameters and sensory attributes. RO = Roe; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

Table 7
Cluster analysis of assessors based on preferences of products from PLS correlation plot.

Attribute	Group 1 (RO)	Group 2 (RM)	Group 3 (RL)	Group 4 (RLM)
RO overall liking average	5.8 (±2.0)	5.9 (±2.0)	4.8 (±2.5)	3.6 (±2.0)
RM overall liking average	3.3 (±1.5)	6.0 (±2.0)	4.2 (±1.9)	4.3 (±2.1)
RL overall liking average	3.6 (±1.8)	4.1 (±2.0)	6.6 (±1.6)	4.3 (±2.1)
RLM overall liking average	3.3 (±1.7)	5.8 (±2.1)	5.3 (±2.7)	5.9 (±1.7)
Average total attitude score[a]	105 (±20.3)	117 (±14.7)	110 (±11.7)	111 (±10.9)
Average willingness to try new seafood products[a]	4.4 (±1.4)	5.0 (±1.6)	4.8 (±1.6)	4.9 (±1.5)
Gender male %	58	62	75	58
female %	42	38	25	42
School geographical location	58% Coastal 42% Inland	86% Coastal 14% Inland	87% Coastal 13% Inland	100% Coastal

[a] Data from attitude to seafood questionnaire. RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

content ranges from 1 to 3 g/100 g while protein content typically ranges from 15 to 24 g/100 g (Bjørndal et al., 2012; Dementeva and Voropaeva, 2014; Egede-Nissen et al., 2012; Huynh et al., 2007). Values of pH (Table 3) indicated that substituting roe with liver (in both RLM and RL) caused significant differences ($p < 0.05$). Overall, RO and RM were similar products based on their proximate composition and pH, while RML had a higher moisture content and lower fat content compared to RL.

Colour values are detailed in Table 3. RO showed the lowest L* value and had the highest a* values, b* value was also the highest though not significantly greater than RL. According to the classification of total colour difference (ΔE) by Cserhalmi et al. (2006), all products exhibited either noticeable (1.5–3.0), well visible (3.0–6.0) or great (6.0–12.0) colour differences (Table 4). The largest ΔE was measured between RO and RL (11.56). Pâté hardness, detailed in Table 3, indicated RL and RLM were hardest as more force was required to penetrate the product (0.92 N, 0.74 N respectively). RO and RM were the softest, requiring less penetration force (0.39 N, 0.36 N respectively). Statistically, these products formed two sub-groups; products containing liver (harder) and products without liver (softer). Pâté hardness was positively correlated to fat content ($r = 0.97$, $p < 0.05$).

3.2. Sensory evaluation

Of the 80 students who attended the workshop, 72 opted to participate in the sensory evaluation session. Students ranged in age from 15 to 16. The gender distribution of the assessors was 61% male and 36% female with 3% preferring not to identify. Most participants (79%) came from a rural background with little prior experience of consuming roe or liver (13% reported to have eaten roe and 6% liver).

TDS curves are presented in Fig. 1 for each product. Fish flavour appeared earliest in oral processing and significantly dominated the palate, followed by perception of saltiness. Savouriness and pastiness

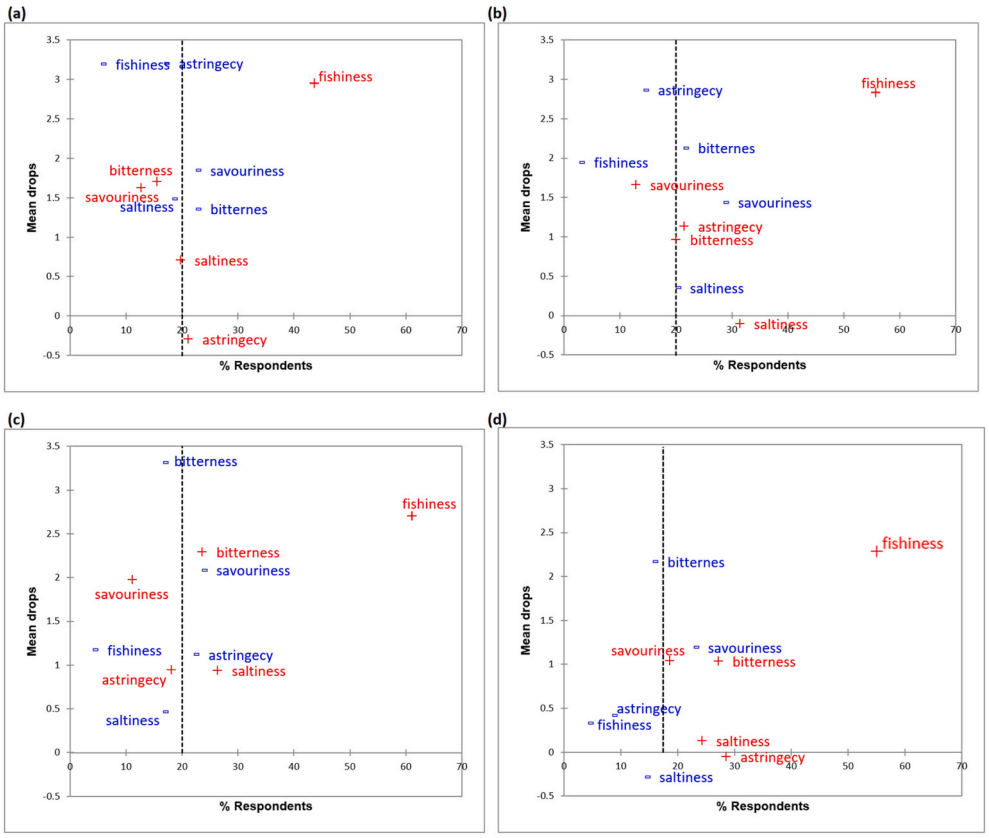

Fig. 3a. Mean drops (penalty) versus percentage consumer responses for Not-JAR attributes. "-" = too little, "+" = too much, dashed line = 20% of consumers. a) Roe only; b) Roe & Milt; c) Roe & Liver; d) Roe, Liver & Milt.

were also noticeable but not significant. The addition of milt in RM appeared to enhance the dominance of fish flavour (Fig. 1b). In RO, the dominance of fish flavour is delayed by approx. 1.5 s compared to all other products (Fig. 1a). The perception of saltiness appeared most intensely in RL compared to all other products (Fig. 1c). It is likely that, given the unusualness of these products, fish flavour overwhelmed the palate and salt was the more familiar and easily identifiable attributes. According to Liem (2017), there is no strong evidence to suggest that children and adults differ in their sensitivity to salt taste. It is proposed that attribute generation in future TDS tests with adolescents be generated by the targeted demographic to enable more familiar attributes to be described.

Although the pâtés consisted of differing quantities of roe, milt and liver, there were no significant differences between group means of attributes (Table 5) as determined by one-way ANOVA ($p > 0.05$). RO received the highest average overall liking score. Average values less than 5 are generally indicative of either poor quality food or foods that are "strange to the observers" (Peryam and Girardot, 1952). Given the unusualness and lack of prior exposure to of these products, the average values of 5 or less may be attributed to the assessor's lack of familiarity with these product types. Unfamiliar (weird) sensory properties can be a driver of rejection of unfamiliar foods (Tuorila and Hartmann, 2020). The cumulative positive responses in the overall liking category (Table 5) indicated that ca. 50% of participants responded favourably to RO and RLM, whereas <40% responded favourably to RL and RM. The substitution of roe with either 25% milt (RM) or 25% liver (RL) impacted liking towards lower overall scores. Whereas the substitution of roe with 12.5% milt and liver (RLM) caused the product to be more closely associated with RO. Overall liking showed high positive correlation to flavour (r_s 0.913 ± 0.024) for all four pâtés indicating the acceptance of flavour was most influential on overall liking of products. In terms of segmentation, between male/female/other, no significant differences in average overall liking were observed (ANOVA $p > 0.05$) indicating similar acceptance of the products across genders. However, there were significant differences between average overall liking of pâtés RM, RLM, and RL between assessors from both schools. The school situated near the Atlantic coast showed higher acceptance of all four products from students (n = 51) with average overall liking from 5.1 to 5.7 when compared to the inland school whose students (n = 21) overall liking averages ranged from 3.0 to 4.1. There was positive correlation between overall liking scores for pâtés and students reported intention to eat these new pâtés as a snack (r_s 0.88, $p < 0.05$) with approx. 33% students responding positively to the new products (Table 6). This is similar to the percentage of students whose overall liking of the products ranged from "like moderately" to "like extremely" (Table 5). PLS regression analysis was used to further investigate the relationship among overall liking scores, physico-chemical attributes and JAR parameters to cluster products, characteristics and preferences (Fig. 2). The PLS regression variable, u1, represents an average assessment of the assessors (panellists) and can therefore be deemed to represent the overall mark of the products attributed by the assessors (Tenenhaus et al., 2005). PLS showed product RO to be most preferable (u1 = 3.811) followed by RM (u1 = 0.966), RLM (u1 = −1.23), then RL (u1 = −3.546). RO was positively correlated with flavour, colour, a* (CIE colour on the red/green spectrum), mouthfeel and aroma, and negatively correlated with fishiness, saltiness and bitterness. The PLS correlation plot shows that substitution of roe with liver (RL and RLM) correlated with perception of astringency, bitterness, saltiness and fishiness. Substitution with milt (RM), while similar to RO by proximate analysis, did not correlate with RO attributes. Clustering the assessors from each quadrant of the correlation plot (Table 7) indicated that students who showed a preference for RO were more likely to be from the school located inland and have a lower attitude towards seafoods. Those who preferred RL, RM and RLM were more likely to be from the

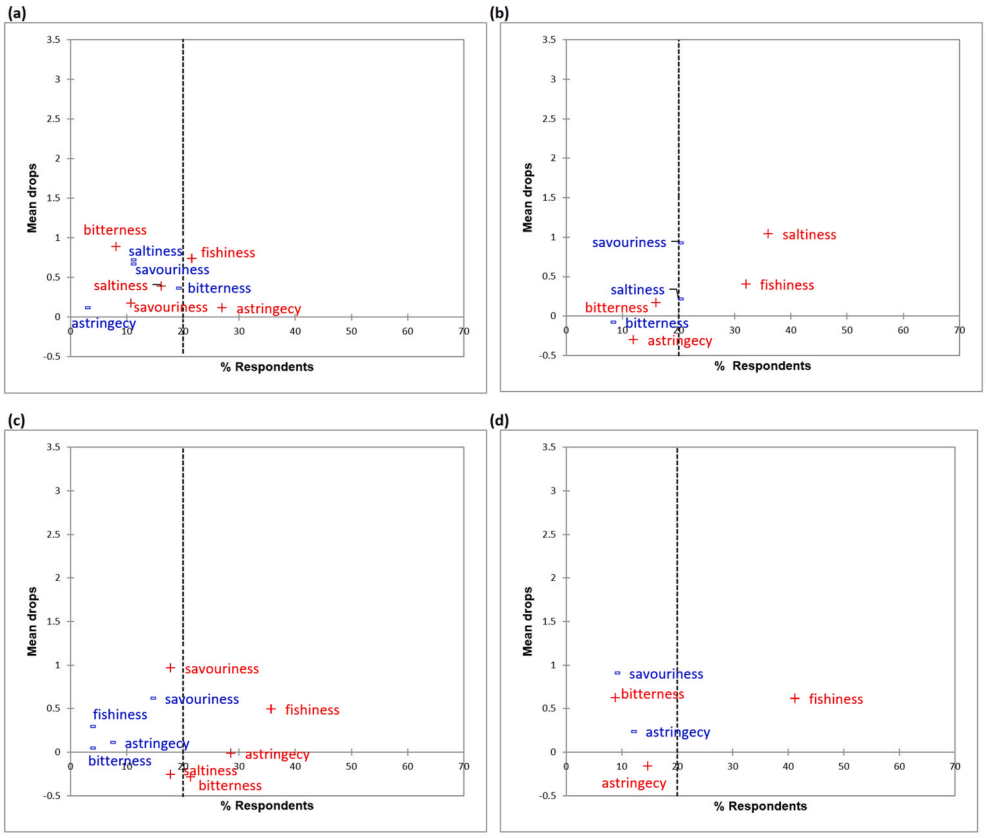

Fig. 3b. Mean drops (penalty) versus percentage responses of Not-JAR attributes for consumers clustered for positive Overall Liking of pâtés. "-" = too little, "+" = too much, dashed line = 20% of consumers. a) Roe only; b) Roe & Milt; c) Roe & Liver; d) Roe, Liver & Milt.

Table 8
Contingency table showing the main modalities for like (L) and dislike (D) comments cited by at least 3 consumers for one or more product, and total like and dislike modalities.

Main modalities[a]	No. of citations			
Like comments (L)	RO	RM	RL	RLM
L-Flavour	16	17	17	26
L-Texture	3	1	8	4
L-Saltiness	2	5	6	3
L-Aroma	1	3	0	2
L-Consistency	0	4	3	1
Dislike comments (D)				
D-Too-fishy	9	17	19	17
D-Saltiness	3	2	5	3
D-Aftertaste	3	10	9	10
D-Flavour	0	6	7	7
D-Appearance	0	6	0	1
D-Texture	0	4	1	3
D-Aroma	1	5	1	0
D-Bitterness	1	5	2	1
Total no. like modalities	***39***	***37***	***30***	***32***
Total no. dislike modalities	***39***	***50***	***43***	***38***

[a] *Modalities mentioned at least by 3 assessors for at least one product. RO) Roe only; RM) Roe & Milt; RL) Roe & Liver; RLM) Roe, Liver & Milt.*

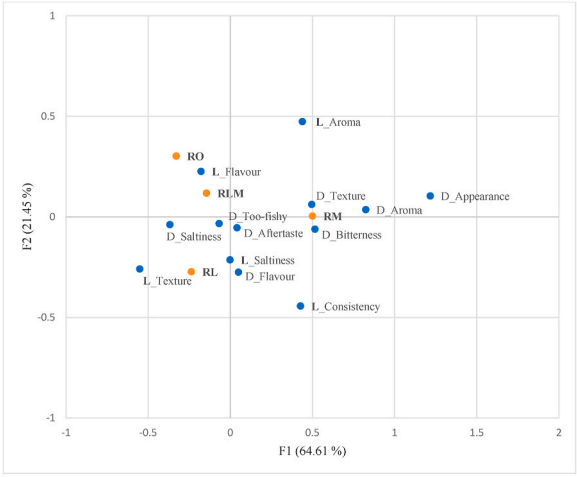

Fig. 4. Correspondence Analysis showing main modalities like (L) and dislike (D) comments cited by at least 3 consumers for one or more pâté: RO = Roe only; RM = Roe & Milt; RL = Roe & Liver; RLM = Roe, Liver & Milt.

school located near the Atlantic coast with those who preferred RL most likely to be male.

Penalty analysis of JAR for all respondents showed level of fishiness ("much too fishy") caused the highest mean drops (penalty) across all four products of 3.0, 2.8, 2.3 and 2.3 for RO, RM, RL and RLM respectively (Fig. 3a). Astringency ("too much") penalised liking of pâté containing milt (RM). Bitterness and to a lesser degree saltiness penalised product liking when considered "too much" by consumers for products containing liver (RL and RLM). Astringency may be explained by the presence of phenolic compounds arising from the plant-based ingredients and possibly bitterness from the variety of peptides and amino acids in the different fish protein sources (roe, milt, liver). Astringency and bitterness can be considered as "twin sensations" as they generally accompany one another and are often confused and used synonymously by panellists (Lea and Arnold, 1978). Following AHC clustering of respondents who expressed positive liking (like slightly to extremely) of pâtés, penalty analysis of JAR showed level of fishiness had less impact

Table 9
Distribution of responses for frequency of seafood consumption (%).

Frequency	%
Everyday	0
4-6 times a week	0
2-3 times a week	9
Once week	27
2–3 times a month	28
Once a month	17
A few times a year	19

Table 10
Contingency table of citations of snack types mentioned by respondents (n = 60).

Snack	Frequency of citation	Snack	Frequency of citation	Snack	Frequency of citation
fruit	27	veg	3	smoked-salmon	1
sandwich	19	crisps	3	pastry	1
crackers	16	rice-cakes	3	smoothie	1
cereal-bar	11	bread	2	bagel	1
chocolate	8	scones	2	waffles	1
toast	8	sweets	2	carbs	1
yoghurt	7	breakfast-cereal	2	wrap	1
biscuits	4	soup	2	jelly	1
eggs	4	rice	2	chips	1
protein-bar	4	chicken	1	curry	1
meat	4	fruit-bar	1	popcorn	1
cheese	4	nuts	1	sesame-sticks	1
pasta	4	energy-bar	1		

on overall liking with mean drop penalties of 0.7, 0.4, 0.5 and 0.6 for RO, RM, RL and RLM respectively (Fig. 3b). There was very little correlation between overall liking and frequency of consumption (r = 0.2).

Responses from open-ended comment type questions (for liking and disliking) were transformed to structured modalities (Symoneaux et al., 2012). Analysis of comment modality contingency table (Table 8) confirmed perception of fishiness as the main factor for disliking of the product, followed by "aftertaste". Bitterness has been reported as a sensory attribute of sea urchin and cod roe (Jonsdottir et al., 2004; Phillips et al., 2009) and in combination with astringency could explain comments on aftertaste. The highest frequency of disliking modalities was observed in RM samples, while the greatest degree liking and disliking of saltiness was observed in RL samples. TDS graphs also showed a higher intensity of salt observed in RL. Correspondence analysis of comments indicated that RO and RLM had the highest association with positive liking of flavour (Fig. 4).

3.3. Attitudes to seafood questionnaire

Sixty panellists fully completed the attitudes to seafood questionnaire, out of those who completed the sensory evaluation session. Regular consumption of seafood was relatively low, with only 9% of students reporting to eat seafood more than twice a week (as recommended in the guidelines by the Food Safety Authority of Ireland (FSAI, 2017)). Overall, 36% of respondents ate seafood once a week or more (Table 9). This is lower than what was reported in a survey by Safefood (2012) where a frequency of fish consumption of 'once a week or more' was 59% across on the Island of Ireland (adult consumers aged 18–64 years). Students seemed unlikely to order seafood when dining out, with only 23% of respondents stating they would order seafood in a restaurant, versus only 8% giving the same response in relation to a school-canteen environment. This indicated most respondents ate seafood predominantly in a domestic setting. The top four preferred seafood species were cod (75%), salmon (67%), prawns (38%) and tuna (36%). Fish was consumed as fresh whole/fillet or frozen/breaded, with 26% consuming tinned fish and 3% reporting consumption of salted roe (caviar or analogue) while no-one reported eating pickled fish. These top four species area in line with BIM's retail value report (BIM, 2018) where salmon was top seller in Ireland followed by cod, tuna and prawns.

The top three snacks eaten most frequently between meals were fruit, sandwiches and crackers (Table 10). When asked if the pâtés spread on toast/cracker could be considered a healthy snack, 67% responded positively whereas only 13% responded negatively.

Cronbach's alpha coefficient of reliability across the group of attitude questionnaire items (Table 10) was 0.832. Attitude scores for each

Table 11
Percentage distribution obtained for each attitude statement from respondents and Kendall correlation between overall liking and attitude variables (n = 60).

Attitude variable	Total disagree (%)	Neither disagree nor agree (%)	Total agree (%)	Kendall correlation with Overall Liking (τ)
Healthy food is important	6	6	88	−0.05
My diet is healthy	8	5	88	0.00
Seafood is good for you	3	10	87	0.19
Seafood is safe to eat	6	10	84	0.04
Seafood is nutritious	7	13	80	0.18
Eating fish is beneficial to health	6	17	77	0.31
Seafood is tasty	16	8	76	0.40
Seafood is rich in omega-3	5	21	74	0.21
Seafood is smelly	15	15	71	0.00
Willing to try new seafoods	17	17	67	0.46
Willing to try new fish species	21	14	65	0.41
Seafood is pleasant to eat	18	19	63	0.50
Texture of cooked fish is pleasant	21	17	62	0.28
I would like to eat more fish in my diet	23	15	62	0.30
Willing to eat farmed fish	12	29	59	0.34
Seafood is easy to cook	11	32	56	0.02
Eating fish is healthier than meat	23	30	47	0.23
Seafood is healthier than meat	18	38	44	0.20
Seafood is mild flavoured	20	41	39	0.19
Seafood is too bony to enjoy	27	35	37	−0.14
Seafood is cheaper than meat	25	43	33	0.01
Seafood is bland	41	30	30	−0.04
Seafood is pleasant in odour	55	19	26	0.21

assessor were summed (with scales for questions 15, 18, 19 and 22 reversed) and compared to overall liking scores which showed positive Kendall correlation ($\tau = 0.40$, $p < 0.05$). Table 11 shows the percentage distribution for items in the attitude questionnaire and their correlation with overall liking. Students generally showed a positive attitude to seafood as a nutritious, tasty and safe product. Their positive attitudes regarding healthiness of fish (77%) was similar to Hicks et al. (2008a) (78%). While students indicated a positive acceptance of texture of cooked fish, fish odour and presence of bones could be barriers to consumption. Overall liking was most positively correlated with those who indicated seafood was pleasant to eat and those who were willing to try new seafoods. Overall liking was most negatively correlated with those who find seafood too bony to enjoy.

4. Limitations

Ideally, consumer acceptance tests should be carried out using assessors who typically consume the type of product being evaluated. However, in this instance such products did not exist and therefore typical teenage consumers were not available. Participants were not screened based on consumption or liking of seafood products.

5. Conclusions

Food products containing fish roe, milt and/or livers are not typically produced or consumed in Ireland. The four pâté's produced which incorporated these underused ingredients received favourable sensory acceptance. Proximate analysis indicated that RO and RM were similar products, compared to RL (highest fat content) and RLM (moderate fat content). However, substitution of roe for milt (25%, RM) while similar from a proximate point of view, were differentiated during sensory evaluations. Sensory and comment analysis indicated that pâté containing only roe (RO) was perceived as most preferable followed by the pâté where roe was substituted with 12.5% milt and liver (RLM). Pâtés with 25% milt/liver (RM/RL), were least accepted. Penalty analysis of JAR responses and comment analysis showed perception of fishiness ("much too fishy") had greatest negative impact on overall liking of all four products. Cluster analysis hints at geographical and gender segmentation of acceptance of products. Acceptance of aftertaste and salt concentration require further investigation in future product development. Reported consumption of seafood was generally low, with 9% of teenagers eating fish twice or more times a week. Students showed a general positive attitude towards seafood and positive sensory acceptance of the new seafood pâté's. This, coupled with willingness to try new fish species/products suggests that highly nutritious marine roe, milt and liver could be incorporated into food formulations of healthy seafood snacks for the Irish teenage market thereby offering an opportunity for Irish Fisheries to add value to lipid and protein rich marine ingredients.

CRediT Author Statement

Furey, A.E.: Methodology, Investigation, Data Curation, Visualization, Formal Analysis, Software, Writing – Original Draft. **Hoeche, U.** Conceptualization, Supervision, Project Administration, Validation, Writing - Reviewing and Editing. **Noci, F.**: Conceptualization, Supervision, Project Administration, Validation, Writing - Reviewing and Editing **McLaughlin, C.**: Resources, Supervision, Project Funding.

Funding

The work was supported by Galway Mayo Institute of Technology (GMIT)/Connacht Ulster Alliance (CUA) PhD Completion Scholarship.

Declaration of interest statement

No conflict of interest was reported by the authors.

Acknowledgements

The author would like to thank the staff and students of the secondary schools who participated in consumer tests.

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